the meaning" of what I wrote, I must leave it to others to settle whether this be in a favourable or an unfavourable sense.

Turning to another matter: in reference to an interesting paragraph on p. 110 concerning the excavation of rock by snails, a subject on which I once wrote (*Geol. Mag.*, 1869, 1870), may I ask whether any of the readers of NATURE are acquainted with instances of these burrows occurring in non-calcareous rocks? All which I have seen were in limestone, and, as I believe, always in a pure variety. Hence, in the case of snails, one would suspect that the excavation was mainly due to chemical action.

T. G. BONNEY.

Coral Reefs, Fossil and Recent.

I SUPPOSE it will be expected of me that I should answer the two objections raised by Captain Wharton (May 22, p. 81), viz. (1) that he knows of no steep submarine reef-slopes exceeding 4000 feet in height; and (2) that the lagoons could not be so shallow as they are if we assumed any extensive positive shifting of the coast-line.

From the statements in the literature on the subject, concerning point (1), I select the following three:—

Captain Fitzroy found at the Keeling no bottom 2200 yards from the breakers with a line 7200 feet long (Darwin, "Coral Reefs").

Bourne says in his account of Diego Garcia (Proc. Roy. Soc., vol. xliii.), that the Maldives, Laccadives, and the Chagos rise from a bank 1000 fathoms below the surface very abruptly.

Heilprin ("Bermudas") states that the Bermudas rise abruptly out of a depth of 12,000 to 13,000 feet.

Concerning point (2), I cannot see why the gentle inward slopes of atolls should not be in harmony with the subsidence theory. It must be borne in mind that the shifting of the coast-line is both slow and oscillating. Positive and negative shiftings alternate. The latter predominates on the whole. Dr. Murray says that in shallow water the accumulation of material exceeds the removal by solution. I have professed my accordance with this view in my previous letter. Particularly in an inclosed or partially inclosed lagoon, sheltered from ocean currents, this filling-up process will be a rapid one. We can easily conceive that it will balance the subsidence until the lagoon becomes so shallow as to impede the life of those organisms whose skeletons form the raising-up deposit. If there is any oscillatory negative shifting of coast-line, the dry rim will rise, and extend horizontally, and afford to the atmospheric agencies a larger surface wherefrom material can be washed into the lagoon.

On the whole, if there is anything difficult to explain, it is that the lagoons are as deep as they are. Deep lagoons are, however, not common, and are generally only met with in large and interrupted atolls. Perfectly dry central depressions (with deposits of gypsum and the like) are by no means infrequent in very small atolls. The general proportionality of the depth and the horizontal extent of the lagoons is perfectly in accordance with the subsidence theory. It supports no other theory better than this one.

R. VON LENDENFELD.

Photographs of Water Drops.

IN NATURE of May 22 (p. 95) there is an account given of the discussion following Mr. C. V. Boys's demonstration of his photographs of falling water drops at the meeting of the Physical Society. In the course of this discussion, Lord Rayleigh, who was naturally much interested in the subject, remarked that it had never occurred to him that it would be possible to get enough light from a single spark to photograph the drops as Mr. Boys had done. And Lord Rayleigh believed Mr. Boys's success was owing to the fact of his using no lenses, which would absorb the ultra-violet rays.

With reference to this, it might, perhaps, be interesting to mention that I succeeded very well, some years ago, in photographing water drops, falling through air, with single sparks, the light of the spark passing two glass lenses and the objective of a camera which gave magnified images. My photographs (copies of which appeared in the *Annalen der Physik und Chemie*, vol. xxx., 1887) show all the forms obtained so very beautifully by Mr. Boys. From photographs taken at different depths below the orifice of the tube I could measure the periodic time of the elliptical vibrations and of the vibrations according to the next higher spherical harmonic, and show that the ratio of these two periodic times agreed very closely with the formulæ given by Lord Rayleigh in the Proc. Roy. Soc., 1879. The amplitudes had no influence upon the periodic times.

Richmond, Surrey, June 6.

P. LENARD.

THE CLIMATES OF PAST AGES.[1]

I.

IT happens sometimes in the history of science that a few striking facts lead to the building up of a far-reaching theory, which at first satisfies us, and with which, without being rigorously critical, we endeavour to bring the further results of experience into conformity. But contradictions and difficulties gradually manifest themselves, and go on accumulating, until at last we are convinced that we have built on an unsure foundation, and that the edifice that we have raised upon it must be utterly pulled down. Then follows a period of discussion and collection of further evidence, during which we abstain from any attempt to substitute new and more correct explanation for that which we have abandoned, until by assiduous labour we shall have prepared a broader and more stable basis for the superstructure.

In such a stage of transition, the old ground abandoned, the new not yet won, is our knowledge of the climatic conditions of our earth in bygone ages. In the far north a rich mass of fossilized plants and coal-beds had been found in the Carboniferous formation. Reef-building corals, such as to-day live only in tropical seas, were yielded by the Carboniferous limestone and the Silurian formation up to 80° of northern latitude; and many of the species were found to range, without any essential change of form, from arctic to temperate, nay in some cases even to equatorial regions. From a small number of data such as these it was hastily concluded that, under the influence of the internal heat of the earth, a warm uniform climate must have prevailed generally from the pole to the equator, while a sultry atmosphere, heavily charged with water vapour and carbonic acid, prevented the sun's rays from reaching the earth or in any case from exercising any considerable influence on it. As a consequence, the existence of climatic zones or of a distribution of the fauna and flora in such zones was denied. It was held that with the beginning of the Tertiary era a polar cooling first set in, and that it increased during its passage, until the present distribution of heat was brought about as the final result of this long-continued process.

The falsity of these assumptions is now pretty generally recognized, and the number of their adherents diminishes daily. It would lead us too far afield were we to follow out the hypothesis into all the details of its ofttimes fantastic errors, and to note their individual failure. It will be more to the purpose if, in the first place, we test the methods by which we arrive at conclusions on the temperature conditions of past ages, in order that we may thus gain a knowledge of what these really were and of the better-grounded attempts to explain them.

Among the more important data for judging of the climate of a past epoch, is the character of its plants and animals, on the assumption that these various organisms must have lived under nearly the same conditions of temperature as their nearest relatives now existing. This kind of reasoning has been very extensively applied, and within certain limits its validity cannot be gainsaid. If, for instance, in a comparatively recent deposit of the Pleistocene period in Central Europe, we find remains of the arctic willow, the dwarf birch, the white dryas, together with such mammals as the lemming, the musk-ox, the glutton, the arctic fox, and also certain snails which, at the present day, live in Lapland or the higher Alps, we may safely conclude that a severe climate formerly prevailed there. An example of the opposite kind is afforded us by the later Tertiaries, which belong, indeed, to a considerably earlier but still not very remote period. Here we find, in our own neighbourhood, a flora of plants with evergreen coriaceous leaves, such as now grow in the warmer parts of the Mediterranean area, and we are quite justified in concluding that a higher temperature was once here prevalent. But, although in many cases such conclusions are well founded, a universal extension of this kind of reasoning leads to deceptive results, and the whole method must be applied with the greatest caution.

---

[1] Translation of a Lecture delivered by the late Dr. M. Neumayr before the Society for the Dissemination of Natural Science, at Vienna, on January 2, 1889.

In the first place, we must bear in mind that, even at the present day, some forms that are nearly related to each other live under very diverse conditions. Antelopes, for instance, are for the most part animals characteristic of warm regions, and yet a kind of antelope, the chamois, lives in a very severe climate in the high mountains of the temperate zone. The arctic fox lives in the far north beyond the polar limit of trees, the Fennec in the burning African desert, and yet the two are nearly related to each other. The elephant and rhinoceros are at the present time peculiar to hot countries, and yet we know from unmistakable evidence that species of both these genera prevailed in Europe and Northern Asia in the cold Pleistocene climate. We have similar instances among marine animals, and we may adduce a whole series of cases in which a group of forms is predominantly peculiar to a certain kind of climate, but have individual representatives living under totally different conditions. The molluscous genera *Voluta* and *Terebra*, for example, are among the most characteristic inhabitants of warm seas, but each of them has a representative in the icy waters of the Magellan's Straits. And among land plants we have the remarkable fact that many forms of the north temperate zone, when they have been transplanted or have escaped to far warmer regions, have extended in an extraordinary manner, and locally to such an extent that they have overpowered and displaced the indigenous flora, as has occurred with the most diverse species of European weeds when transported to foreign countries.

On the whole, we are inclined to infer that, with the exception of the Pleistocene fauna and flora, the animal and plant remains of past ages, in their generality, point to a warmer climate than that which we now experience; and in point of fact, several very striking items of evidence lead to that conclusion. The most important is the very great extension of reef-building corals in the older deposits, while their modern representatives are restricted to the warmer seas.

Many other instances of the same kind may be quoted, while in other cases similar conclusions have been somewhat uncritically based on insufficient evidence. Thus, some have inferred the prevalence of a high temperature from the abundance and occasional great size of the chambered-shelled Cephalopoda, solely because the last existing representative of this once widely distributed group, the well-known Nautilus, happens to live in a warm sea. This conclusion is quite unjustified, for it is obvious that the many thousands of extinct species must have lived under very varied conditions; and if we are to infer, from the great size of these creatures, that they lived in warm seas, we ignore the fact that the largest Cephalopoda of the present day, the cuttle-fishes, are most prevalent in the northern part of the temperate zone.

But even when we have excluded all such evidently erroneous cases, the number of those in which fossil forms do really present the characters of types highly characteristic of warm regions is very considerable. It is true, that the opposite case sometimes presents itself, though less frequently. Thus, in all the older formations, a group of Bryozoa, the Cyclostomata, is extensively distributed, but it is now especially preponderant in the circumpolar seas. The molluscous genus *Astarte*, so common and widely distributed in Mesozoic deposits, is at the present day entirely restricted to cold seas; and there also occurs the last representative of the once widely spread genus *Cyprina*. The Brachiopodous genus *Rhynchonella*, common in the Silurian formation, and especially abundant in the Jurassic and Cretaceous formations, is now a form of high northern latitudes, and the Squaloid genus *Selache*, now restricted to the seas of Greenland, occurs in Cretaceous deposits in much more southerly latitudes.

Such instances, and they are far from singular, teach us, unmistakably and assuredly, that animal and vegetable types are not unchangeable in respect of the external conditions of their existence, and especially of temperature, but that they are capable of accommodating themselves to changed circumstances. Whether, then, we infer that reef-building corals formerly lived in cooler waters, or that Cyclostomoid Bryozoa frequented warmer waters than at the present day, or finally that both have changed their habit of life, the conclusion is overwhelmingly forced upon us that organisms continually adapt themselves to changed temperatures, and in a far higher degree than has generally been supposed.

In connection with this, we may notice a very remarkable circumstance, viz. the great vitality, adaptability, and toughness of the organisms of the temperate and especially the north temperate zone, when transported to other parts of the globe. Just as European man carries on a successful struggle with the children of all other zones of the earth, so also do the animals and plants indigenous to Europe, and especially those of its central and northern parts. As already remarked, when they are transplanted to foreign countries, they extend rapidly, and often drive out the indigenous forms; English naturalists who have had most opportunities of observing these relations in their colonies, speak expressly of the great aggressiveness of North European organisms.

At the present time, when the dissemination of the most diverse forms is brought about in the highest degree by world-wide human intercourse, such displacements present themselves in a particularly striking manner, and yet similar processes must have gone on, more slowly indeed, but on a far greater scale, for many millions of years. At some given epoch, a certain assemblage of organic forms appears in moderately cold regions, from which colonists wander away southwards; these gradually adapt themselves to the new local conditions, and spread still further, until, at last, their further progress is stayed by some natural barrier. They become acclimatized under the new conditions and the higher temperature, and become enfeebled; but in the meantime new forms have been developed in their former home, which in their turn pursue the same course and suffer the same fate; and thus the southern types always display a certain relationship to the older forms of the northern region, without any change having supervened in the temperatures of their respective stations.

We now see with how great caution we must proceed, when we attempt to draw any inference as to the temperature of former ages from the relationship of species, stratigraphically remote, with those of the existing organic world. The danger of error is here very great, and it is the greater and more menacing, the older the deposit the climatic conditions of which are in question; obviously, the probability of a change having taken place in organic constitution with regard to temperature is the greater, the more remote the epoch with which we are dealing. While, therefore, we may deduce conclusions having some claim to probability, on the climatic conditions of Pleistocene and Tertiary times, even in the Mesozoic deposits such conclusions become doubtful, and quite untrustworthy when we are concerned with Palæozoic times. We must, indeed, admit that as the result of more searching criticism, and the increased knowledge of the facts which the labours of many years have now amassed for us, we are not in a position to answer that most important and fundamental question whether a continuous and universal cooling of terrestrial climate has or has not been progressing from the time of the earliest stratified deposits down to the present day.

The difficulties with which we have to contend in dealing with this problem may be illustrated by a very significant example. The fact has already been noticed that reef-building corals occur only in warm seas, in which, throughout the year, the surface-temperature never sinks below 20° C. If now we compare the geographical distribution of the reef-building corals of the older formations, we find in very early times, in Silurian and Carboniferous deposits, the remains of such corals beyond the Arctic circle; at a much later period in the Jurassic formation, we find that they reach only to North Germany and to Southern England; during the second half of the Cretaceous formation, they do not pass the northern limit of the Alps and the mountains of Southern France, and their northern limit in the first half of the Tertiary era is nearly the same. At the beginning of the second half of the Tertiary era, we find them but scantily represented on the northern boundary of the Alps, and abundant only in Southern Europe; and in the latest subdivisions of the Tertiaries, in Pliocene times, they have almost disappeared from Europe.

From these facts it might seem almost a manifest conclusion that there has been a continuous fall of temperature since Silurian times, in consequence of which reef-building corals have retrograded through some fifty degrees of latitude; nevertheless, on closer examination, we find that such an inference would be altogether premature. In the first place, the Palæozoic corals differ very essentially from those that now exist, and therefore their requirements in respect of warmth may have been totally different; further, we have no knowledge of any coral reefs in the far north in all the older formations; and between the Carboniferous and Jurassic formations which we have cited, there intervene the Permian and the Trias in which we know of no reef-building corals so far north; the most northerly representatives of the group in Permian times appear in North-Western India, those of Triassic times in the Alps. We are therefore absolutely ignorant whether these changes of distribution, supposing them to have depended on the temperature, are not to be ascribed to alterations in the distribution of temperature, while there may have been no continuous cooling. Lastly, it is by no means definitely ascertained that the position of the earth's axis has always been the same as at present; indeed, there are in the course of geological time certain definite epochs pointing to such a displacement of the poles, of which we have yet to gather the meaning. It may therefore be the case that those parts of the earth at which we find Silurian and Carboniferous corals in the neighbourhood of the pole, were much nearer the equator in those early times than they now are.

Similar difficulties present themselves in all our attempts to arrive at far-reaching conclusions by this method, and thus we are admonished how great caution must be exercised in the face of so many sources of error. Another method, by means of which it has been sought to attain some holding ground for determining the climatic characteristics of early times, is that, leaving out of consideration the conditions under which nearly related organic types exist at the present time, we should simply regard the extent of the geographic distribution of extinct organisms, and from their wide distribution conclude the existence of a uniform climate over very great areas, nay even over the entire globe. But in such an attempt the risk of over-estimating the facts is imminent, and especially is this true in the case of marine organisms; in a former state of our knowledge, we might well have believed that ancient forms of life had a wider distribution than such as now exist, since our knowledge of the tenants of the present seas related almost exclusively to those of shallow water and the coasts, many of which have a restricted range. But from the epoch-making deep-sea soundings of the last decennia, we have learned much of the inhabitants of the depths of the ocean, and have become aware that they possess much the same characters in all parts of the world; so that, in this respect, there is no essential difference between the present and former ages. As a fact, we have ascertained, from the distribution of organic life, that climatic zones existed in most of the early periods, and that this has not been done in some cases may be simply ascribed to the fact that they have not yet been rightly investigated.

Side by side with the diverse indications afforded us by the animal and vegetable worlds, regard must be had to the petrographic characters of the old deposits. We have rocks which have issued from the interior of the earth and have solidified from the fluid state, others have been deposited from water, and in the formation of others, again, ice has played an important part, and this mode of formation is generally recognizable by well-marked characters. For our present purpose, only such masses are important as have been transported by ice and thus brought to their present position, for these alone furnish us with conclusions as to temperature conditions; they inform us that, whenever they occur, the cold has been, at least at times, sufficiently great to freeze large masses of water.

The marks of ice action are well known. A moving glacier polishes and scores or scratches its rock floor, and carries with it fine silt, sand, great and small stones, and even mighty boulders, and deposits these materials in its moraine, without sifting them according to magnitude, as in the case of transport by water. Polished and grooved rock surfaces, scratched pebbles, and deposition without stratification in a confused mixture of silt, sand, coarse pebbles, and enormous blocks, are the indications of glacier deposits; in the identification of which, nevertheless, great caution is necessary. If a glacier reaches the sea or a great lake, under certain conditions, masses of ice may be floated away to great distances, carrying with them the enclosed stones and boulders, and often deposit them when thawed out of the iceberg, on the sea-bottom at great distances from their place of origin. Thus the deep-sea investigations of the *Challenger* show that, in high southern latitudes, in the deep sea and far from any coast, numerous stones lie scattered on the fine silt of the ocean-floor, and these can have reached their present position only by such means of transport. Such indications are, however, not quite undeceptive, since it sometimes happens that stones are transported in the roots of trees which are carried by rivers into the sea; but this kind of transport is operative only to a very small extent. When, however, we find in old formations water-formed deposits of fine clay or sand extending over great areas, in which numerous great stones and boulders are promiscuously intermingled, we may infer that they have been transported by floating ice, especially when the stones moreover are scored.

We have now learned what are the most important indications from which we may draw inferences as to the climatal conditions of past ages, and we have endeavoured to ascertain how far, and within what limits, such inferences are legitimate. Our next task will naturally be to apply the conclusions thus established to the phenomena which we meet with at different epochs of the past, and to form a conception of the climatic relations of those times, and of the conditions depending on them. It would, however, lead us too far afield were we to discuss each period in detail, and we must restrict ourselves to a hasty sketch of a few especially important formations that have been closely studied.

We pass over the oldest deposits, for the interpretation of which but few points of vantage present themselves, and we shall fix our attention on the upper half of the Carboniferous formation, the so-called Coal-measures. It has received this name because in many countries it contains those thick beds of fossil fuel which have become an indispensable factor of modern industries, and without which the actual status of our social and political condition could not have been attained. So great is the quantity of the fuel herein stored, that all that is furnished by other geological formations, taken together, falls far short of it. There is much difference of opinion as to the mode in which coal has been formed; but whatever disagreement there may be in matters of detail, this much is certain, that we have in coal the altered remains of a land-vegetation, which, partly at least, flourished in swamps. Of course the formation is not all or even chiefly coal; even where it is richest in coal, by far the greater part of the formation consists of shale, sandstone, and conglomerate, and the coal-beds are here and there interstratified, forming but a fraction of the total thickness. We may picture to ourselves the building up of the formation by supposing that a plain or depression was sometimes covered with water, sometimes dried up. When flooded, chiefly with fresh and but rarely with sea-water, beds of shale or sandstone were deposited; when dry, land or swamp plants sprang up, and their decayed remains furnished the material of coal. Then followed another period of inundation, and thick beds of shale, sandstone, and conglomerate were again deposited. . . .

The vegetation that in its decay formed our beds of coal was of a peculiar character. As yet there existed no trees (with true foliage) and no flowering plants. A monotonous growth of plants with stiff leaves then clothed our continents. A great part in it was played by *Calamites*, great plants which no longer exist, and whose nearest relatives are the mares' tails so often met with in marshy ground; another important type was that of the *Lepidodendra*, large trees whose forked stems were covered with leaf scars arranged in a regular geometrical pattern, and the branches of which were clothed with short, stiff, grass-like leaves; and most important of all, the *Sigillarias*, the unbranching and twigless stems of which were marked with leaf scars in perpendicular rows and scale-like leaves. Both of these are long since extinct; and only the insignificant club-mosses of our present flora recall to us the varied gigantic forms of that distant age.

H. F. B.

(*To be continued.*)

LIGHTNING AND THE ELECTRIC SPARK.[1]

AT a date at least as remote as 600 years B.C. the Greek philosophers were acquainted with a curious little fact to which the modern science of electricity owes its name. They knew that a piece of amber (*ἤλεκτρον*) when rubbed against some suitable substance acquired a temporary attractive power, in virtue of which it became capable of lifting and holding light objects, such as dry leaves or pieces of straw. But another remarkable effect which often attends the friction of amber was for many centuries altogether overlooked. In A.D. 1708 it was first noticed by Dr. Wall that a piece of strongly excited amber emitted sparks, which were accompanied by crackling sounds, and these he had the sagacity to compare to thunder and lightning.

It must be confessed that the recognition of any resemblance between the microscopic scintillations thus produced and the brilliant lightning flash imposed a somewhat severe strain upon even the scientific imagination, and a few years later Stephen Gray, in reference to the same comparison, expressed the hope that "there might be found out a way to collect a greater quantity of the electric fire" than was then possible. His hope was realized by the subsequent improvement of electrical apparatus, and especially by the invention of the Leyden jar; and the effects obtainable by the means now at our command amply justify the speculations of Wall and Gray. The essential identity of the artificial electric spark with the natural lightning flash was conclusively established by the experiments of Franklin, and in these days it has become a mere common-place, familiar to everyone.

There are generally said to be two kinds of lightning flash, which are known as forked lightning and sheet lightning, the former being dangerous and destructive, the latter harmless. To these is sometimes added a third class, called ball lightning. The lightning flash of artists which is familiar to us from innumerable pictures, and of which the venomous-looking zigzag now projected upon the screen (copied from an engraving) is a fair example, has no existence in nature. It is simply an artistic fiction or symbol, like the conventional representation of a galloping horse, which, in the severe language of Mr. Muybridge, resembles nothing to be found in the heavens above or in the earth beneath. The absurdities commonly perpetrated in depicting animals in motion have been fully exposed by Mr. Muybridge with the assistance of photography. So, too, it is photography that has given the *coup de grâce* to the traditional forked lightning. Within the last few years an immense number of photographs of lightning flashes have been made. The Meteorological Society has formed a collection of these, containing about 200 examples, which, by the kindness of Mr. Marriott, the Secretary of the Society, I have had an opportunity of examining carefully. Not a single instance of the artistic lightning flash is to be found among them. The great majority bear a close resemblance to the sparks of our electrical machines: a few are distinguished by peculiarities which, though at first sight a little difficult to account for, can generally be explained and even imitated artificially.

What may be called a typical lightning flash is a stream of light which follows a sinuous and wavering course, very like that of a river as shown upon a map. [Several photographs of this kind of flash were exhibited by means of the lantern.] The next slide is a photograph of a machine-spark, about 3½ inches in length. The two kinds of discharge are so much alike in their general character that if it were not for the surroundings it would be hard to tell which was the lightning and which the artificial spark.

The variations upon the normal type of flash, which the Meteorological Society's photographs show, have been classified as ramified or branched lightning, beaded lightning, meandering or knotted lightning, ribbon lightning, and, lastly, dark lightning.

Branched lightning is again strikingly suggestive of a river in a map; not a simple stream, however, but one into which a number of tributaries flow. [Photographs were shown.] Sparks having branches of just the same character are easily produced by a large electrical machine. To obtain the effect well, the negative terminal should be made much larger than the positive, and the two should be separated so far that a spark will only just pass between them. According to Faraday, a ramified, or as he sometimes calls it a "brushy," spark occurs when the whole of the electricity has not been discharged, but only portions of it, more or less, according to circumstances. It is a "dilute" spark, generally passing to air or other badly conducting matter ("Exp. Res.," § 1448). When therefore a ramified flash occurs we may reason-

---

[1] Extracted from a lecture on "Electrical Phenomena in Nature," delivered by Mr. Shelford Bidwell, F.R.S., at the London Institution on February 10, 1890.